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Experimental Study on Performance of Recycled Concrete Aggregate as Course Aggregate and Silica Fume As Partial Replacement for Cement with Different Water Binder Ratio

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I. Chapter

1.1 INTRODUCTION:

One of the construction sector's major contributions to the preservation of the environment and sustainable development is the reuse and recycling of the waste materials it generates (reducing, reusing, recycling and regenerating the residues that originate the constructive activity). One way of achieving this is to introduce recycled aggregates from construction and demolition debris and rubble into the production processes. This increases the life cycle of these materials, thereby reducing the amount of waste dumping and natural resource extraction.

1.2 ADVANTAGES OF RECYCLED CONCRETE AGGREGATE

There are many advantages through using the recycled aggregate. The advantages that occur through usage of recycled aggregate are

1. Environmental Gain
2. Save Energy
3. Cost

1.3 SILICA FUME IN CONCRETE:

The American concrete institute (ACI) defines Silica fume as, "Very non-crystalline silica produced in electric furnaces as a by product of the production of elemental silicon alloys containing silicon" Silica fume usually referred as

1) Condensed Silica Fume
2) Micro Silica
3) Volatized Silica.

1.4 SCOPE OF THE INVESTIGATION:

- To determine the strength characteristic of Recycled Concrete Aggregate and to determine the optimum level of replacement of Natural Coarse Aggregate by Recycled Concrete Aggregate
- To determine the strength characteristic of concrete by adding the Silica fume as a partial replacement for different water- binder ratio and to conduct the durability studies.

II. Chapter

2.1 PROPERTIES OF MATERIALS

2.1.1 INTRODUCTION

Experiments were conducted to study the physical and mechanical properties of materials such as Cement, Sand, Natural Coarse Aggregate and Recycled Concrete Aggregate (NCA & RCA) the results are shown in Table 2.1 to 2.4.

2.1.2 SILICA FUME

Table – 2.1 Chemical Properties of Silica fume

Constituent	Percentage (%)	Constituent	Percentage (%)
SiO_2	90-96	Na_2O	0.2-0.7
Al_2O_3	0.5-0.8	K_2O	0.4-1.0
MgO	0.5-1.5	C	0.5-1.4
Fe_2O_3	0.2-0.8	S	0.1-0.4
CaO	0.1-0.5	Loss of Ignition	0.7-2.5

2.1.3 RECYCLED CONCRETE AGGREGATE

Table – 2.2 Properties of RCA

Sl .no	Properties	0% RCA + 100 % NCA	10% RCA + 90% NCA	20% RCA + 80% NCA	30% RCA + 70% NCA	40% RCA + 60% NCA	50% RCA + 50% NCA
1	Specific gravity	2.81	2.85	2.70	2.85	3.05	3.27
2	Impact value in percentage	16	20.8	21	22	22.7	23.6
3	Los Angeles Abrasion value in percentage	28.5	29	29.5	29.7	30.6	31.4
4	Aggregate Crushing Value	28.25	29	29.3	29.8	32	33.25

2.1.4 WATER ABSORPTION FOR (NCA & RCA)

For Natural Coarse Aggregate = 9.8%
For Recycled Concrete Aggregate = 12.7%

Fig.2.1 RCA, NCA, Super Plasticizer & Sulphuric acid

2.1.5 SUPER PLASTICIZER

Super plasticizer used in this investigation is Conplast SP430 which is Sulphonated Naphthalene polymer based one and supplied as a brown liquid instantly dispersible in water.

Table 2.3 Properties of Super Plasticizer

Form	Liquid
Color	Brown
Specific gravity	1.23
Chloride content	Nil
Solid content	0.48

2.2 MIX PROPORTIONING

2.2.1 TRIAL MIX PROPORTIONS

Trial mixes were obtained by replacing natural coarse aggregate by replaced coarse aggregate at a replacement level of 10%, 20%, 30%, 40% and 50%. They are designated as TM_1, TM_2, TM_3, TM_4, TM_5 and TM_6. The compressive strength of various trial mixes are given in the Table 2.7

Table 2.4 Compressive Strength of Various Trial Mixes

Trial mix	TM1	TM2	TM3	TM4	TM5	TM6
% of RCA	0	10	20	30	40	50
7 days (MPa)	26	24.2	23.97	23.23	21.75	20.02
28days(MPa)	49	48.62	48.02	47.77	46.2	44.1

From the Table it is found that 30% of natural aggregate can be replaced by recycled aggregate.

Hence in this thesis all the mixes contain 30% of Recycled Concrete Aggregate (RCA) and 70% of natural coarse aggregate.

The following specimens are cast to study the mechanical properties of conventional and recycled concrete.

Table 2.5 Specimens Details

S. No	Properties Studied	Specimen's Shape	Properties Studied	No. of Specimens	Specimens Size in mm
1	Concrete Strength Properties	Cube	Compressive Strength	3X5X15=225	150X 150X150
2		Prism	Flexural Strength	3X5X3=45	100X100X500
3		Cylinder	Split Tensile Strength	3X5X6=90	150X300
4	Test on Beams	Rectangle	Flexural Strength	3X2=6	100X200X200 0

2.3 EXPERIMENTAL PROGRAMME

2.3.1 PARAMETERS STUDIED

The experiments are conducted on five series of test specimens. The following properties were studied for all the three grades of concrete.

Mechanical Properties

- ✓ Compressive strength of concrete – cubes
- ✓ Compressive strength of concrete – cylinders
- ✓ Split tensile strength of concrete – cylinders
- ✓ Flexural strength of concrete – beams

Durability Studies

- ✓ Modified Sorptivity
- ✓ Sulphate Resistance
- ✓ Chloride Resistance

2.3.2 DESCRIPTION OF TEST PROGRAMME

2.3.2.1 WORKABILITY

The workability is defined as the property of concrete which determines the amount of useful internal work necessary to produce full compaction.

2.3.2.2 MEASURMENT OF WORKABILITY

The following tests are commonly employed to measure workability.

- ❖ Slump cone test
- ❖ Compacting factor test

2.3.2.3 SLUMP CONE TEST

Slump cone test is the most commonly used method of measuring consistency. It doesn't measure all factors contributing to workability; it is used as a control test and gives an indication of uniformity of batches. The addition of super plasticizer gives workability to the concrete mix. The obtained test result for various percentage of replacement of RCA with different percentage of Super plasticizer for different mixes is shown in Table 2.6.

Table- 2.6 Slump Cone Test Results

Mix		M I	M II	M III
Fly ash (%)	**Super plasticizer (%)**	**Slump in mm**	**Slump in mm**	**Slump in mm**
0	1.25	30	28	28
10	1.25	28	30	27
12.5	1.50	27	29	30
15	2.00	24	25	23
17.5	2.50	26	29	28

2.3.2.4 Compacting Factor Test

Compacting factor test is more precise and sensitive than the slump cone test. This test gives an idea for degree of compaction and adopted to find the workability of concrete where aggregate size does not exceed

20mm and the mixes are comparatively dry. The obtained test results for various percentage of fly ash, for different mixes are shown in Table2.7.

Table- 2.7 Compacting Factor Test Result

MIX		M I	M II	M III
Silica Fume (%)	**Super plasticizer (%)**	**Compacting Factor**		
0	1.25	0.97	0.96	0.94
10	1.25	0.95	0.95	0.96
12.5	1.50	0.97	0.97	0.98
15	2.00	0.95	0.98	0.98
17.5	2.50	0.95	0.94	0.97

The compacting factor test results given in Table 2.7 shows that as the percentage of super plasticizer increases, the compaction factor increases. It also shows that the addition of super plasticizer enhance more workability to the mix which it is added.

2.3.2.5 Compressive Strength of Cylinder

Fig 2.2 Compressive Strength of Cylinder & Cube

2.3.2.6 Split Tensile Strength of Cylinder

The cylindrical specimens of size 150mm x 300 mm are used to determine the split tensile strength as per IS: 516 – 1959. Typical test setup for testing split tensile strength of cylinder is shown in Figure 2.3

Splitting tensile strength = 2P / πDL

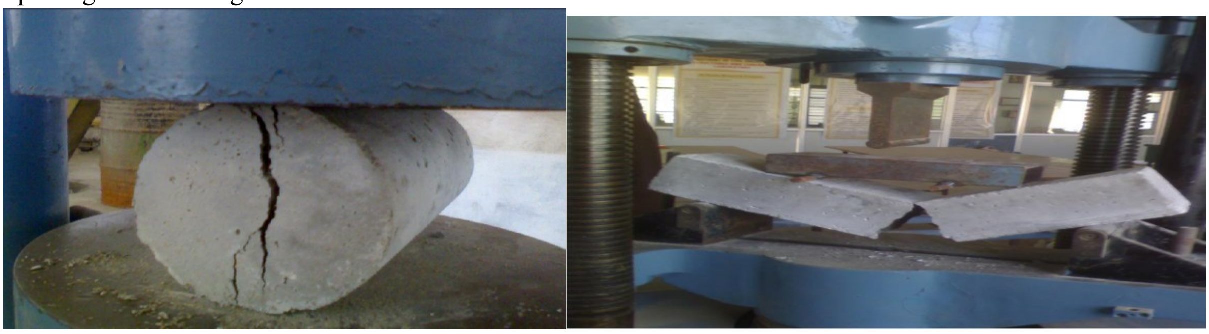

Fig 2.3 Split Tensile Strength of Cylinder & Flexural Strength of Beams

2.3.2.7 Flexural Strength of Beams

Test was carried out at the end of 28 days using Universal Testing Machine (UTM) of 400 KN capacity.

Flexural Strength $F_f = PL / BD^2$

P = max load in N applied to specimen

L = length in mm of span as which specimen was supported.

B = measured width of specimen in mm

D = measured depth of specimen in mm]

2.4 Design of Flexure beam

The beam can be broadly divided into two regions. In region-I (section 1-1), the bending moment is less than the cracking moment (M_r) of the section with the result that every section in this region remains fully un cracked and the complete section is effective in resisting bending moment, Therefore, the moment of inertia I of the section for deflection calculations is I – the moment of inertia of concrete gross cross – section or of the transformed gross section.

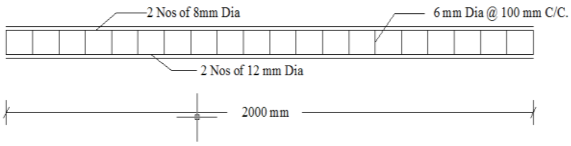

Fig:2.4 Reinforcement details

Fig 2.5Reinforcement for Flexure Beam

Fig 2.6 Beam after casting

2.4 EXPERIMENTAL SET UP

These beams were tested on a span of 1500mm with simply supported conditions under two point loading. Deflections were measured under the loading point and at the mid span using Linear Variable Differential Transducers (LVDTs). The crack patterns were also recorded at every load increment. All the beams were tested up to failure.

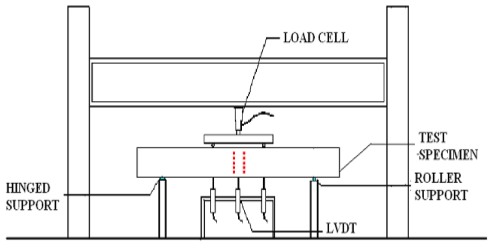

Fig 2.7 The Schematic Diagram Of Loading Set-Up

Fig 2.8 Arrangement of Pivots for Strain Measurement and LVDTs for Deflection Measurement

2.5 TEST RESULTS AND DISCUSSION

Table 2.8 Cube Compressive Strength for M I Mix

Silica Fume (%)	7 days (MPa)	14days (MPa)	28 days (MPa)	56 days (MPa)	90 days (MPa)
C	30.8	37.2	47.77	49.6	52.22
10	29.74	37.9	47.98	50.85	53.7
12.5	32.96	40.45	49.94	52.43	55.5
15	30.42	36.03	46.8	48.9	52.4
17.5	20.16	35.76	44.7	46.84	49.2

Table 2.9 Cube Compressive Strength for M II Mix

Silica Fume (%)	7 days (MPa)	14 days (MPa)	28 days (MPa)	56 days (MPa)	90 days (MPa)
C	27.72	33.26	42.65	44.8	46.92
10	28.8	36.1	45.12	47.8	50.6
12.5	30.4	36.8	46.1	49.3	51.2
15	29.58	34.4	44.16	46.8	49.6
17.5	26.78	32.2	41.87	43.9	46.12

Table 2.10 Cube Compressive Strength for M III Mix

Silica Fume (%)	7 days (MPa)	14 days (MPa)	28 days (MPa)	56 days (MPa)	90 days (MPa)
C	25.89	32.5	41.12	43.17	45.23
10	20.3	34.3	42.9	45.5	48.3
12.5	30	34.5	44.2	46.8	49.2
15	21.3	33.3	42.1	44.6	47.3
17.5	20.3	31.2	39.5	41.4	44.2

2.8.1.1 Graphical results for Compressive Strength of cube

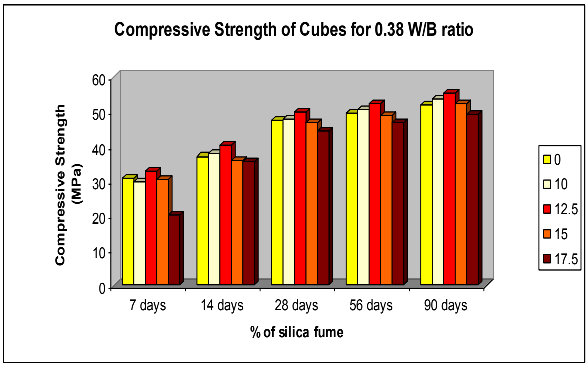

Fig 2.9 Cube Compressive Strength for M I Mix

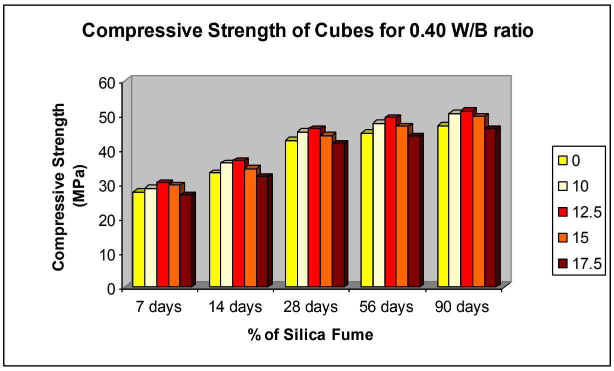

Fig 2.10 Cube Compressive Strength for M II Mix

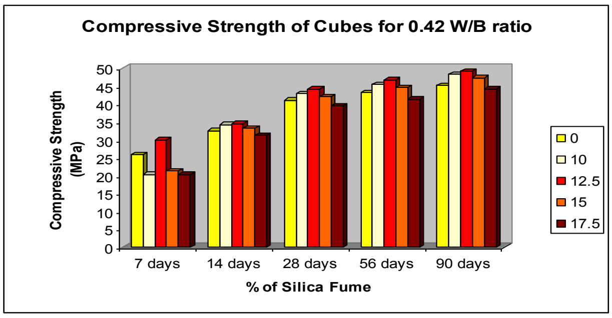

Fig 2.11 Cube Compressive Strength for M III Mix

Graphical results for compressive strength of cube for M I, M II & M III

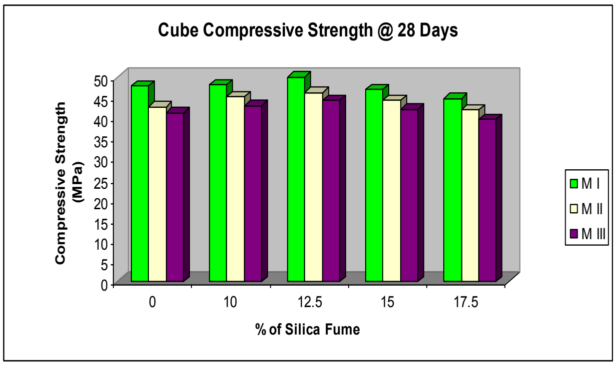

Fig 2.12 Cube Compressive Strength for 28 days

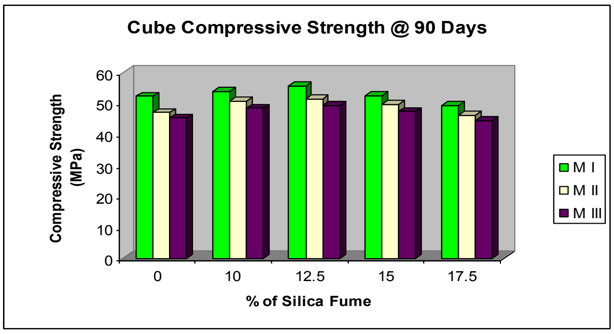

Fig 2.13 Cube Compressive Strength for 90 days

From the above results it is observed that the strength increases with the age of curing and strength increase with increase in the Silica Fume content up to 12.5 % replacement by 2 – 10 % and there after increase in Silica Fume reduced the compressive strength by 4 – 17 % when compared with control mix. With increase in the water content compressive strength reduced by 5 – 13 %

2.5.2 Compressive strength of cylinder

The average compressive strength of cylinder obtained is shown below in the Table.

Table 2.11 28 Days Cylinder Compressive Strength for M I Mix

Silica Fume in (%)	Compressive Strength in MPa		
	MI	MII	MIII
0	41.5	40.9	38.7
10	38.9	37.6	36.7
12.5	40.4	38.5	37.8
15	37.5	36.2	35.4
17.5	35.8	33.5	32.6

Graphical results for Compressive Strength of Cylinders

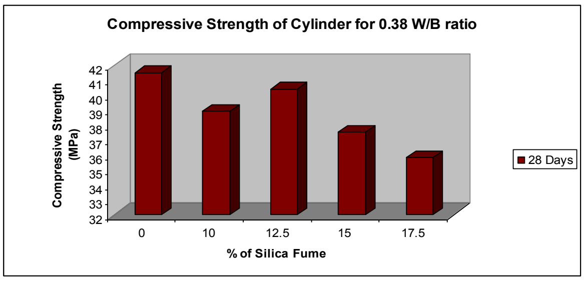

Fig 2.14 Cylinder Compressive Strength for M I Mix

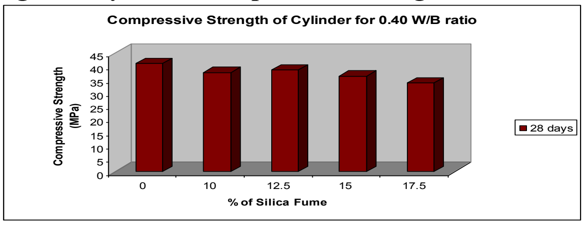

Fig 2.15 Cylinder Compressive Strength for M II Mix

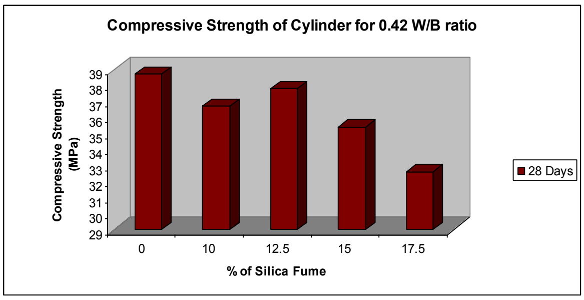

Fig 2.16 Cylinder Compressive Strength for M III Mix

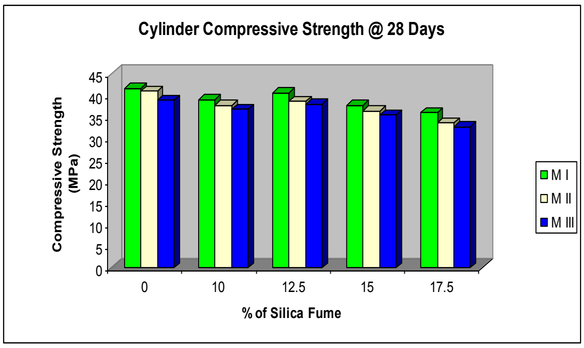

Fig 2.17Cylinder Compressive Strength for M I, MII, MIII Mix

From the above results it is observed that the compressive strength of concrete mixes containing Silica Fume increased up to 12.5% replacement by 3 – 6 % and there after increase in Silica Fume reduced by 15 – 27 % when compared with control mix. With increase in the water content compressive strength reduced by 5 – 13 %

Table 2.12 28 Days Split Tensile strength for M I Mix

% of Silica Fume	28 Days Strength (MPa)		
	MI	**MII**	**MIII**
0	3.89	3.72	3.47
10	3.87	3.47	3.45
12.5	3.81	3.52	3.4
15	3.66	3.25	3.2
17.5	3.57	3.12	3.02

Graphical results for split tensile strength

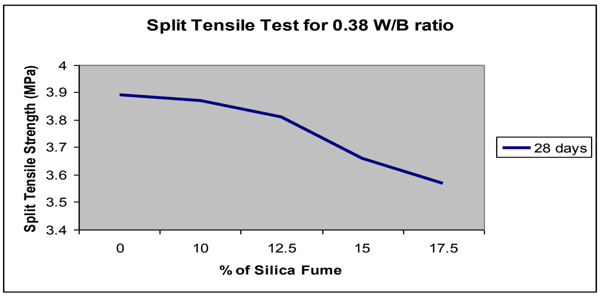

Fig 2.18Split Tensile Strength for M I Mix

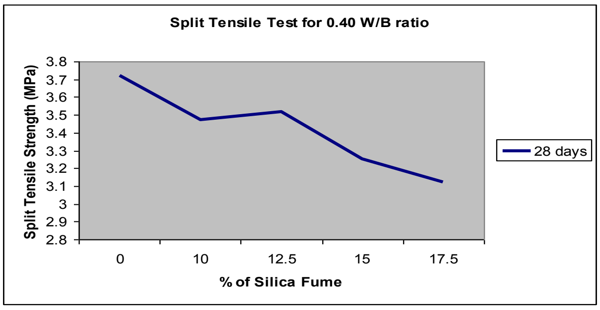

Fig 2.19Split Tensile Strength for M II Mix

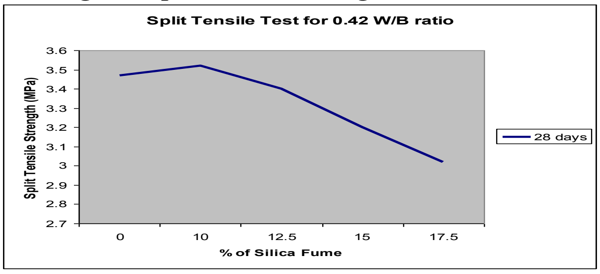

Fig 2.20 Split Tensile Strength for M III Mix

Graphical results for Split Tensile strength of cylinders for M I, M II, M III.

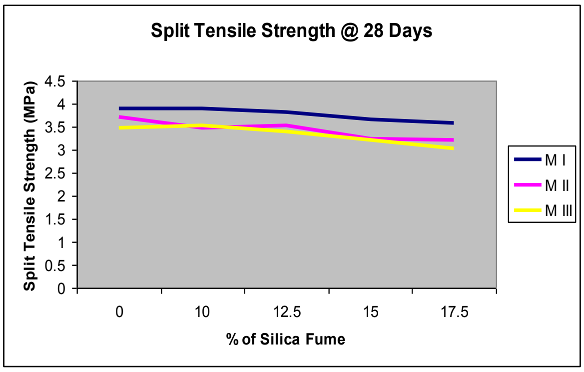

Fig 2.21 Split Tensile Strength for Various Mixes

From the results it is observed that the Split Tensile strength of concrete mixes containing Silica Fume increased up to 12.5% replacement by 2 – 7.5 % and there after increase in Silica Fume reduced by 9 – 20 % when compared with control mix. With increase in the water content split tensile strength reduced by 8 – 14 %

2.5.4 Flexural Strength of beams

The modulus of rupture test is conducted on beam of size 100 x100 x 500mm after a curing period of 28 days with the help of universal testing machine (UTM) of 400KN capacity.

Table 2.13 28 Days Flexural strength for M I Mix

	% of Silica Fume	28 Days Strength (MPa)		
		M1	MII	MIII
C	0	5.05	4.61	4.41
10	10	4.81	4.62	4.52
12.5	12.5	4.86	4.7	4.6
15	15	4.51	4.4	4.38
17.5	17.5	4.34	4.2	4.2

Graphical results for Flexural Strength of beams

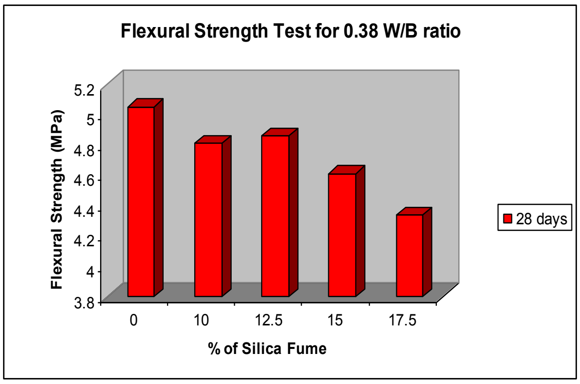

Fig 2.22 Flexural Strength for M I Mix

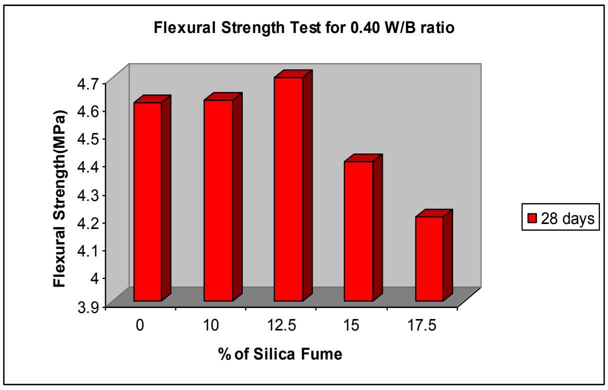

Fig 2.23 Flexural Strength for M II Mix

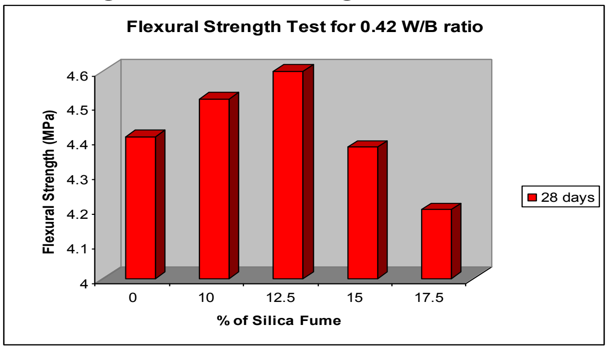

Fig 2.24 Flexural Strength for M III Mix

Graphical results for Flexural strength of beam for M I, M II, M III.

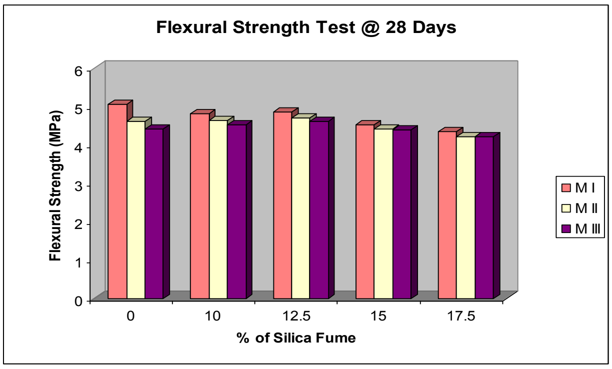

Fig 2.25 Flexural Strength for Various Mixes

2.5.5 Flexural Beam

Table 2.14 - Flexural Test Results for Beam Specimen

Description of test specimens	% of Silica Fume	First Crack load (kN)	Ultimate Load (kN)	Deflection at Ultimate Load (mm)
0.38 Control	0	28	49	18
0.38 Silica Fume	12.5	33	60	19.46
0.40 Control	0	26	48	21.3
0.40 Silica Fume	12.5	29	54	22.75
0.42 Control	0	23	44	22.67
0.42 Silica Fume	12.5	27	51	22

Comparison of First Crack Load and Ultimate

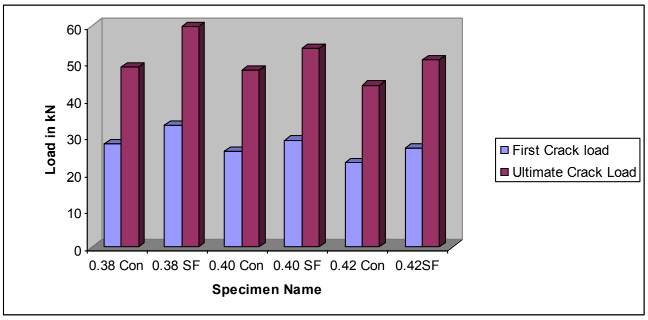

Fig 2.26 Comparison of First Crack Load and Ultimate Load

2.8.5.1 Load versus Deflection (P-Δ) Curves

Load versus Deflection curves for the beam specimen tested for Flexure are Shown below. Comparison of (P-Δ) curves for beam specimens 0.38 Control, 0.38 SF, 0.40 Control, 0.40 SF, 0.42 Control, 0.42 SF are shown below.

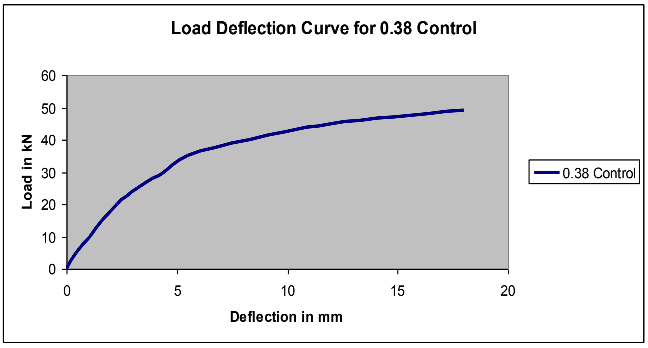

Fig 2.27 Load Vs Deflection for 0.38 Control Mix

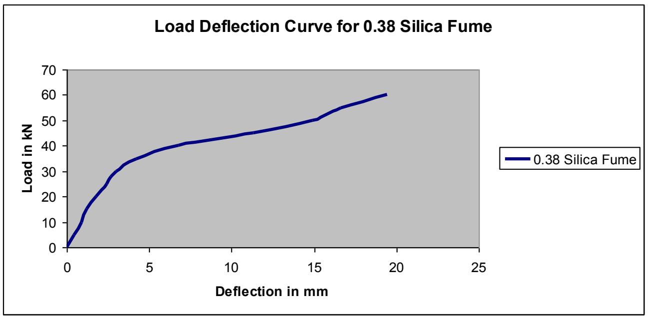

Fig 2.28 Load Vs Deflection for 0.38 Silica Fume Mix

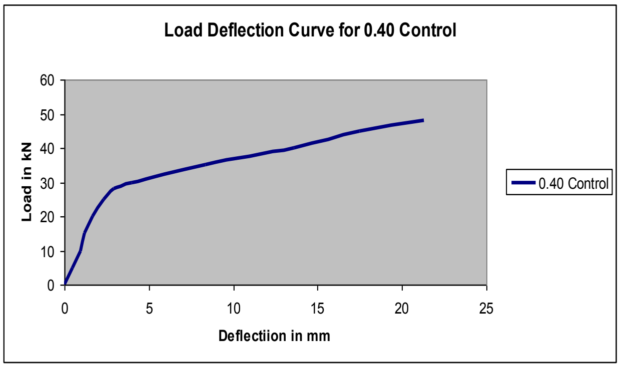

Fig 2.29 Load Vs Deflection for 0.40 Control Mix

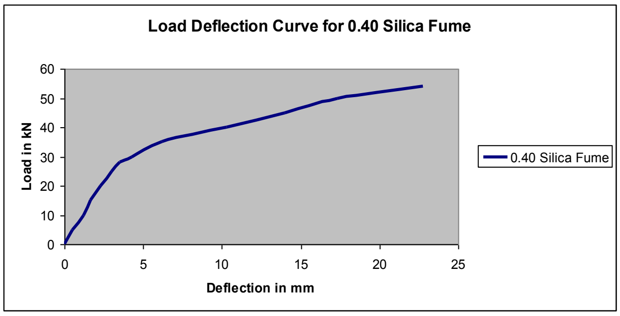

Fig 2.30 Load Vs Deflection for 0.40 Silica Fume Mix

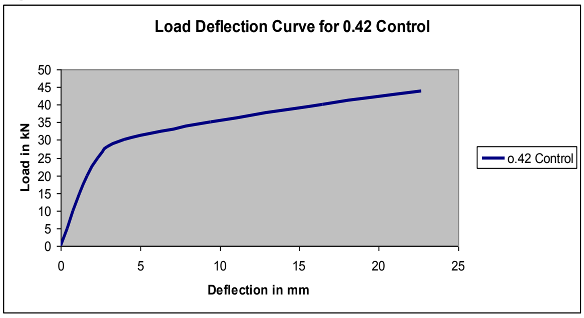

Fig 2.31 Load Vs Deflection for 0.42 Control Mix

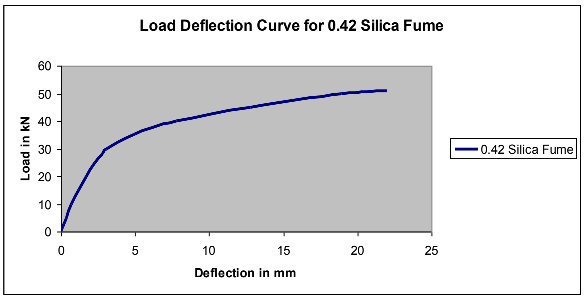

Fig 2.32 Load Vs Deflection for 0.42 Silica Fume

Fig 2.33 Crack Pattern of Flexural Beam

Reference

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